Microcars

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Edited by

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Design for Transport

A User-Centred Approach to Vehicle Design and Travel

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Microcars

Brian Clough

Introduction

The motor car as we know it is just over a century old and during its existence it has changed little. In the early days there may have been competition between electric power and the internal combustion engine but a plentiful supply of cheap oil and two World Wars saw oil dominate as the most reliable fuel and the commodity upon which much of the world economy developed through the twentieth century. However the early years of the twenty-first century have been fraught with new realizations; that oil will not last forever given the current rate of consumption and that emissions from burning petrochemicals are causing irreparable damage to the planet and changing the climate. The energy consumed in creating and scrapping automobiles far outweighs that consumed in their operational life. As new, populous economies emerge and grow wealthy their inhabitants want to share in the freedom the automobile brings. However the future of the car as we know it, a one-ton steel box with four seats, four wheels, top speed in excess of 100 mph and range of 350 miles is unsustainable. As experts predict that peak oil may be reached in the first half of the twenty-first century (Aleklett et al., 2008) there has never been a greater imperative to change the way that we design, build power and use motor cars.

Possible solutions may include:

- downsizing cars to use less materials and take up less physical space;
- creating more efficient vehicles that are fitter for purpose and that provide flexible packaging solutions;

- making use of sustainable materials and processes in manufacture;
- creating longer life vehicles;
- using alternative or renewable fuels to power vehicles;
- applying telematic systems to guide vehicles and prevent collisions, to reduce stop-start energy wastage and to allow vehicles to travel in closer proximity making better use of existing road space;
- changing attitudes to car use and pricing entirely.

And so, if we accept that the contemporary fossil-fuelled motor car is unsustainable then we must also accept that the car industry is on the verge of a paradigm shift of unprecedented proportions. We simply cannot continue to expend so much energy in creating one tonne steel cars which will be scrapped after 10 years. Not if the world car population is set to double and the oil supply is set to decline in the next 50. There is simply too great an energy investment in each unit and too great a CO^2 output from the production and life cycle.

The recent history of the design of microcars is one of repeated attempts to address these social and consumer needs and wants, in circumstances where energy supply has looked increasingly precarious. There has been increasingly an ethical and political need to develop transport solutions which reduce our carbon footprint.

Car Design

Car design is mainly undertaken in large design studios with big teams of designers following styling and design methodologies established by the great Harley Earl at GM in 1937. Often led by the styling, their goals are to imbue brand values and identity to products that must sell in huge volumes in order to recoup their development costs. However, some automobiles defy the usual conventions and may be conceived by happy amateurs or in some cases defiant professionals keen to challenge contemporary thinking by adopting unusual methodologies or processes. Typical amongst products conceived in this way are 'Microcars', which often stem from the ideas and philosophies of individuals who possess vision, an inherent degree of aesthetic appreciation and importantly the technical knowledge to realize their ideas. Many microcar designers are by necessity 'creative engineers'.

What Defines a Microcar?

To answer this question we must first understand what does *not* constitute a microcar. The automotive industry is very conservative. Myriad legislation controls every aspect of design, construction and use and consumers find it easier to compare and to categorize products that subscribe to recognized norms. Hence nearly all manufacturers build mainstream vehicles that are conceptually and dimensionally similar within recognized 'classes' (Figure 7.1). Different variants may be offered, based on the A–E segment platforms such as three-, four- and five-door versions, people carriers, estate cars, coupes and convertibles (and increasingly folding hard top 'coupe cabriolets').

Branding adds another dimension within each category so vehicles can be perceived as 'mainstream' or 'premium'. The Ford Focus and Opel Astra

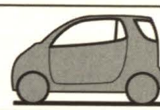
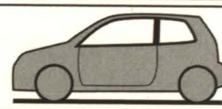
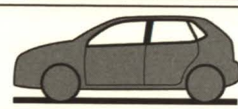
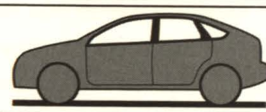
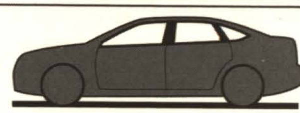
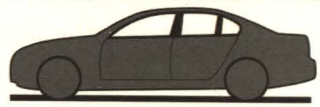
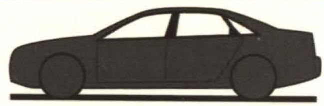
Class	Description	Examples	Typical Size mm	Pictogram
Sub A	Micro Car	Toyota iQ, Smart ForTwo	L = <3000 W = 1600 H = 1500	
A	City Car	Ford Ka, Opel Agila, VW Fox, Fiat 500, Seat Arosa, Suzuki Swift	L = 3500 W = 1600 H = 1500	
B	Supermini	Ford Fiesta, VW Polo, Opel Corsa, Audi A1, Mini Cooper, Seat Ibiza, Mazda 2	L = 3700 W = 1600 H = 1500	
C	Small Family Car	Ford Focus, VW Golf, Opel Astra, Audi A3, BMW 1 Series, Mercedes B-Class, Mazda 3	L = 4200 W = 1750 H = 1500	
D	Large Family Car	Ford Mondeo, VW Passat, Opel Insignia, Audi A4, Mercedes C-Class, BMW 3 Series	L = 4800 W = 1750 H = 1500	
E	Executive Car	Audi A6, BMW 5 Series, Jaguar XF, Mercedes E-Class	L = 5050 W = 1800 H = 1500	
F	Luxury Car	Audi A8, BMW 7 Series, Jaguar XJ, Mercedes S-Class,	L = 5100 W = 2100 H = 1500	

Figure 7.1 **Car class sizes**

are typical mainstream C-Segment cars whilst the Audi A3 and BMW 1 Series are seen as premium with commensurately higher price tags. Recent niche products include C-Segment compact SUVs such as the Nissan Qashqai, Ford Kuga, and Volkswagen Tiguan which are sold with the promise of greater ecological acceptability than traditional large four-wheel-drive SUVs. Some versions are even offered with front-wheel-drive-only for lighter weight and greater economy.

Conservatism also extends to engineering and architecture. With few exceptions today's cars are powered by internal combustion, be this gasoline (petrol), diesel (mineral or bio fuel), alcohol (bio-ethanol is a renewable fuel derived from starch and sugar yielding crops) or liquefied petroleum gas (LPG). Several companies offer, or have in development, production hybrid cars and Honda is already series-producing the hydrogen-fuel-cell-powered Clarity though both types still sit within conventional class segments. Most companies offer at least one all-electric car by simply 'shoe-horning' an electric drive train into an existing platform. Unfortunately, large battery stacks may replace seats reducing vehicle practicality and additional batteries may be needed for higher speeds or increased range which eats into payload and upsets weight distribution. Hence *converted* electric vehicles come with compromises.

Nearly all mass-manufactured car bodies use welded steel unitary (monocoque) assembly for speed and efficiency. The current exceptions are Jaguar and Audi who employ aluminium, though only the latter has produced a *small* mainstream aluminium car, the Audi A2.

Most conventional small cars can travel at speeds approaching 90 mph for 350 or more miles between fuel stops. Even 'city cars' have four or five seats, usually equally sized, forward facing and distributed in a regular pattern (to cater for occupants ranging from 2.5 percentile female to 97.5 percentile male). Car companies now also live in a 'turnkey' world where specialist component suppliers 'badge-engineer' complete, and substantially similar, systems for many manufacturers. The subsequent demand for economies of scale also influences why cars fit so tightly into the A–E segments.

Some manufacturers *have* begun to challenge these stereotypes but high-volume cars are still constrained by construction and use regulations and legislation governing occupant safety as well as vehicle-to-vehicle and vehicle-to-pedestrian impact performance. Though legislation currently provides a disincentive for big car makers to innovative it has not prevented the emergence of very short cars such as the Smart ForTwo (formerly City Coupe) or the recent Toyota iQ, though both incurred high development costs to meet the stringent safety rules for larger cars. Despite being so small they are relatively expensive.

And so, in defining the 'Microcar' this chapter will consider vehicles that are not easily categorized in terms of the known market segments referred to above yet which were produced in sufficient quantities to make them significant. Some are unique due to their size, or their architecture, or due to the use of unusual drive train and power sources. By the definition used in this chapter a true Microcar is one designed from the ground up rather than based upon existing products. Most will be forms of transport which offer a true alternative to the types of car we are currently familiar with.

What Are the Generic Design Drivers for Microcars?

Alternative vehicles like microcars often appear in response to socio-economic stimuli or as a result of new commercial opportunities resulting from technology push or consumer-led market pull. Some may be developed within a mainstream car company by traditionally trained automotive designers 'thinking small' but others have resulted from an individual's genius or determination to challenge the status quo. Some of these entrepreneurs do not have automotive backgrounds and can apply fresh thinking (even if not all of the vehicles have been successful). The history of automobile design is already well documented so this chapter will mainly concentrate on the period from the early 1960s until the present time and will highlight a few significant products listed below.

Microcars Designed by Mainstream Manufacturers

- Kei Cars (Japan)
- Smart Car (Switzerland/Germany/France)
- Tata Nano (India)
- Toyota IQ (Japan)
- Renault Twizy (France)

Microcars Designed by Engineers and Innovative Individuals

- Bubble Cars (Germany and Italy)
- Fiat Topolino/500 (Italy)
- Mini (United Kingdom)
- Peel Cars (Isle of Man)
- Sinclair C5 (United Kingdom)
- Voiturettes (France)
- Quadricycles (Pan Europe)
- Peraves Ecomobile (Switzerland)
- The Narrow Car Company (Prodrive) NARO (United Kingdom)
- Commuter Cars Corporation 'Tango' (USA)
- GoinGreen G-Wizz (United Kingdom – *manufactured in India*)
- Think City (Norway)
- Gordon Murray Design T25 and T27 (United Kingdom)
- Toyota Personal Mobility Concepts: i-unit, i-swing, i-foot, i-REAL (Japan)
- Segway HT (Human Transporter) and PT (Personal Transporter) (USA)
- Segway P.U.M.A. (Personal Urban Mobility and Accessibility) (USA)
- Segway/GM/SAIC EN-V (Electric Networked-Vehicle) (USA/ China)

Microcars Designed by Mainstream Manufacturers

KEI CARS (JAPAN)

Japan is the modern spiritual home of the microcar or Kei Car (sometimes simply K-Car). The term comes from the Japanese word for 'light automobile', keijidosha, a category of very small passenger cars and light commercial vehicles governed by legislation specific to Japan. After the Second World War most Japanese could not afford full-size cars but motorbikes were popular. Kei car standards were originally introduced to promote the growth of the Japanese domestic car industry and to provide affordable transport for small businesses and shops.

The standards have changed over the years (Figure 7.2) but modern Kei cars still exploit local tax and insurance advantages and are exempt from the requirement to prove the availability of an officially recognized parking space in rural areas.

Date	Max length	Max width	Max height	Maximum displacement		Maximum power
				2-stroke	4-stroke	
July 1949	2.8 m	1 m	2.0 m	150 cc	100 cc	n/a
July 1950	3.0 m	1.3 m	2.0 m	300 cc	200 cc	n/a
August 1951	3.0 m	1.3 m	2.0 m	360 cc	240 cc	n/a
April 1955	3.0 m	1.3 m	2.0 m	360 cc		n/a
January 1976	3.2 m	1.4 m	2.0 m	550 cc		n/a
March 1990	3.3 m	1.4 m	2.0 m	660 cc		47 kW (63 hp)
October 1998	3.4 m	1.48 m	2.0 m	660 cc		

Figure 7.2 Evolution of Kei Car regulations

Under current rules, last updated in October 1998, a Kei car must meet specific criteria for size, engine capacity and power output as follows:

Max. length: 3.4 m

Max. width: 1.48 m

Max. height: 2.0 m

Engine capacity limit: 660 cc

Max. power: 63 bhp

Before March 1990 regulations only restricted physical size and engine capacity not engine power so turbo charging was common. Even after a 63bhp limit was imposed manufacturers continued to introduce advanced technologies to the class to maintain the levels of performance and comfort. This includes forced induction (turbo-charged) engines, automatic and CVT transmissions, air conditioning, GPS and many other features. Different Kei cars can be had in front-, rear- and 4-wheel-drive layouts with body styles ranging from 2-seat sports cars to micro-vans and pick-up trucks. All offer a good balance of performance and economy and under Japanese road laws they are much cheaper to tax and run than 'full size' cars.

In summary Kei cars are very small but technologically advanced, well equipped and half as expensive to run as 'normal' cars in their native Japan but their appeal has spread far beyond the country in which they originated. Kei cars are manufactured by the big companies using all their engineering strength and so their development follows traditional automotive design studio methodology. The styling of many Kei cars is rather boxy to make maximum use of the footprint and height limits, and many use unfashionably small wheels to reduce wheel arch and suspension intrusion into the passenger cell. However, interior and exterior styling is still very sophisticated on many examples.

SMART (GERMANY) – CASE STUDY

The Smart ForTwo (formerly City Coupe) is now in its second generation (Figure 7.3). It was the brainchild of one man, Nicholas G. Hayek (Lewin, 2004, 35), who ran a management and engineering consultancy in Switzerland advising big clients such as AEG. In the 1980s Hayek revived a watch industry that was dying due to outdated manufacturing methods and competition from cheap quartz watches from the Far East. Hayek had the brilliant solution of developing a common Swiss-made quartz movement module for all brands to share which would reduce costs and simplifying assembly procedures. The module could be used inside all watches from profitable high-value brands to big volume, low-cost, products without affecting the perceived value (Swatchgroup.com). His personal masterstroke was creating a new brand to market the cheaper, high-volume watches as a colourful fashion item.

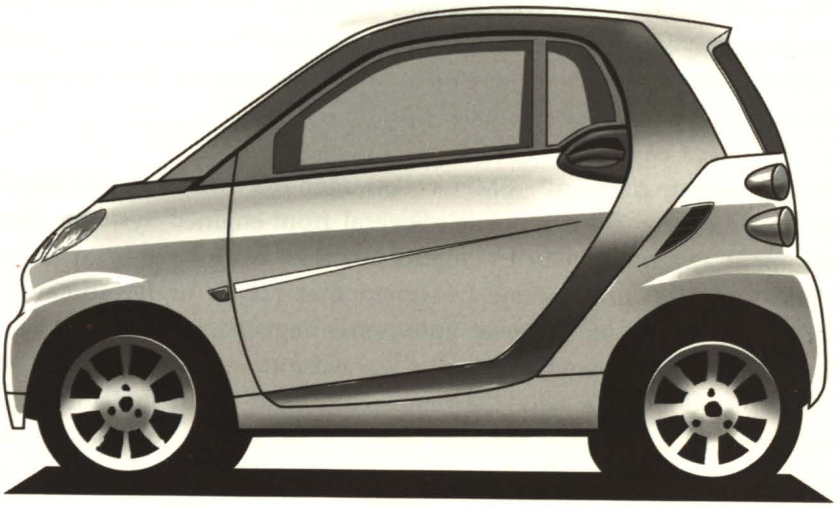


Figure 7.3 Smart ForTwo Mk2
Source: Author.

Moulded in plastics and sold for a modest premium price to increase margins the 'Swatch Watch' became a 'must-have'. The price was cleverly pitched low enough that the watch could be replaced with the latest style when the owners tired of it (or added to their growing collection). The Swatch brand was born in 1983, by the end of 1984, 10 million Swatch watches had been sold and shortly before its twentieth birthday sales reached the 300 million mark.

Buoyed by the success of Swatch, Hayek believed the same cost-cutting philosophy could be used to develop a Swiss car-manufacturing industry. He dreamed of an ultra-small two-seat city car short enough park end-on to the kerb to reduce city congestion. Like the Swatch Watch he envisaged a well-priced fashionable product with interchangeable plastic panels that could be updated as fashions changed. It should also be environmentally benign with a battery or hybrid drive train. Initially Hayek began work himself through his Swatch holding company SMH and in 1990 engaged Swissauto-Wenko to develop power trains for his 'Swatchmobile'. He saw these drive-trains as 'the automotive equivalent of the standardized quartz movement' (Lewin, 2004, 39).

Although a superb brand strategist Hayek was not an automotive designer and recognized the need to work with a major car company. Respected in the business community, it was easy for him to engage with the highest levels of automotive company management. Volkswagen had a brand chief called Daniel Goeudevert who was open to new ideas and so became the first company to collaborate with Hayek (Lewin, 2004, 45).

A joint venture company – SMH Volkswagen AG - was set up in July 1991 to develop the new 'Swatchmobile'. Several front-engined systems were in development and mule vehicles created but they were beset with technical problems and VW also became frustrated that Hayek underestimated the amount of work needed to meet automotive legislation (Lewin, 2004, 48). VW's own research showed the market wanted four seats not two and when VW Group appointed a new chairman, Ferdinand Piech in January 1993, he withdrew from the joint venture and VW went on to develop its own, conventional, four-seat car the Lupo.

Within a year Hayek had joined forces with another unlikely partner, Mercedes Benz, whose latest Mercedes flagship, the W140 S-Class, was selling badly, leading to their first-ever loss in 1993. This, and fears about the approaching California Zero Emissions Legislation and Corporate Average Fuel Economy regulations across the rest of the USA, was leading to a rethink in Mercedes Benz which then only made large luxury sedan cars. All auto companies were being compelled to include smaller, more economical cars or risk heavy 'gas-guzzler' fines (Lewin, 2004, 65).

M-B was already working on a small concept car called the 'Vision A' (later to become the A-Class) and another Mercedes Benz designer, Johann Tomforde was working on rear-engined two-seater concepts prefixed 'Eco' at their California design studio. Hayek saw Mercedes as a natural ally (or potentially powerful rival) whilst Mercedes Benz in turn knew that Hayek had innovative marketing ideas and could attract younger buyers. Between March and April 1994 a new joint-venture Micro Compact Car AG (MCC-AG) was founded and two two-seater concept cars were revealed, the Eco Sprinter hard-top and the Eco Speedster Cabriolet. Both were in fact entirely based on the short-wheelbase, rear engine concepts of Johan Tomforde.

Three power trains were considered: economical internal combustion engines, electric drive with high efficiency batteries and a hybrid drive system. Hayek always wanted electric or hybrid but cost and technical limitations finally led to a car with turbo-charged petrol and diesel engines. Hayek's underestimation of the amount of development needed created new tensions with his partner. In 1997 Mercedes Benz injected capital into MCC-

Figure 7.4 Smart product range
Note: Left to right – Forfour, Roadster, Roadster Coupe
Source: Copyright of Daimler AG.

AG reducing Hayek's share and during the merger with Chrysler to form Daimler Chrysler in 1998 his remaining share was bought out and Hayek had no further part in the car. Work was completed by Mercedes Benz engineers and the car taken to production by Mercedes Benz senior managers brought in to run the company MCC-AG. The original MCC Smart (as it came to be called) went on sale in 1998.

Like most ground breaking products, sales were initially slow but gradually the Smart Coupe began to gain acceptance. New products were introduced to broaden the brand's appeal including the Roadster and Roadster Coupe in 2003, and the four-seat Mitsubishi Colt-based 'Forfour' in 2004 (Figure 7.4). Although the new range helped Smart to become an established company worldwide the new models sold poorly and were discontinued in 2006. However, in 2007 a revised Smart ForTwo was introduced with styling gently evolved from the original but 200 mm longer and 240 mm wider. Conceptually it remains true to the 1998 Smart City Coupe and is still one of the most innovative cars in production.

The Smart ForTwo grew out of one man's belief that the world was ready for a new, intelligent kind of car designed, manufactured and sold in a completely new way but such was the complexity of the task that it required the enormous design and engineering ingenuity of Mercedes Benz to realize the vision.

TATA NANO (INDIA)

The Tata Nano is not really a microcar but deserves mention. In terms of concept and engineering it is utterly conventional – yet it claims to be the world's cheapest car (Figure 7.5) and Tata has hopes of producing a version of the car that can achieve four-star Euro NCAP rating before going on sale in the UK in 2012 (Arron, 2009). Unveiled at the Delhi Auto Expo on 10 January 2008 the car was the brainchild of the company chairman Ratan Tata who announced that, 'This is a car that is affordable and provides all-weather transport for the

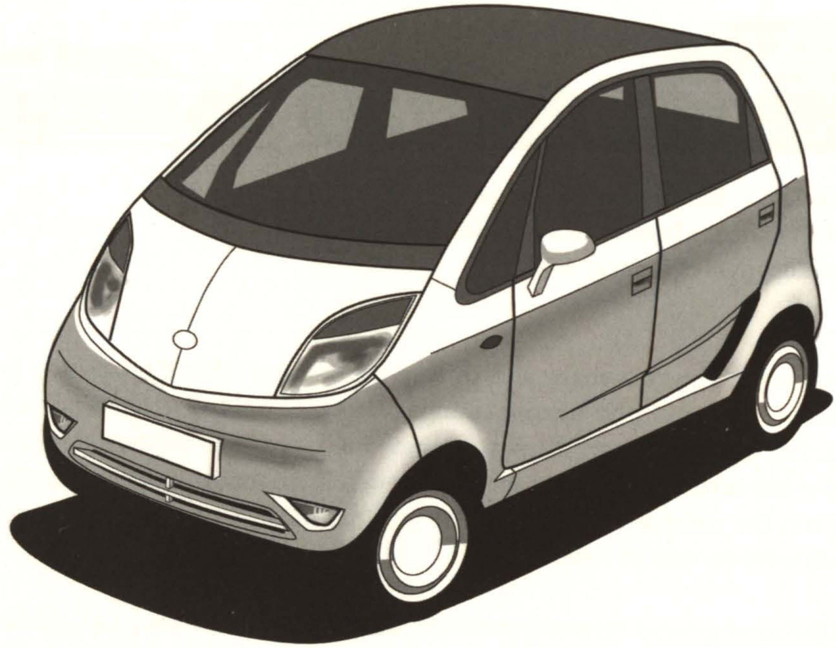


Figure 7.5 Tata Nano
Source: Author.

(Indian) family'. The Nano is being marketed as a safer way of travelling for those who until now have carried their families balanced on the back of their motorbikes.

At 100,000 rupees (£1,390), the Nano, studio-designed and manufactured in India by Tata, is 3.29 metres long and 1.58 metres wide and can best be described as India's 'people's car'. The Nano car is expected to sell for a few hundred pounds more than the most popular motorbikes and less than half the price of the next cheapest car on the market, a Maruti 800 (Honestjohn.co.uk). The Nano benefits from a minimalist approach without unnecessary frills and with pure transportation its key goal. Designed as an all-weather alternative to the motorcycle the model produced for the domestic market in India has the following specification:

Length: 3100 mm

Width: 1300 mm

Height: 1600 mm

Top speed: 65 mph

Engine: rear-mounted 623 cc, 33 bhp multipoint fuel injection engine

Transmission: continuous variable transmission or four-speed manual, rear-wheel drive

Fuel consumption: 50 mpg

Body: sheet metal with crumple zones

Weight: 600 kg

Performance: 17 sec 0–60 mph, 65 mph, 60 mpg, 100 g/km CO^2 (est)

The standard car has no air conditioning, airbags or radio, just a single wiper and only the driver's door has a mirror. It also runs on 12-inch road wheels (small by today's standards until one remembers the original Mini ran on 10-inch wheels). The 100-litre boot can only be accessed by folding the rear seats forward – to save cost.

For all its low cost and minimalist philosophy the Nano is a very low-tech solution to India's transport problems and not without its critics. Ashling O'Connor wrote in Times Online on 11 January 2008 that 'the idea of millions of Nanos on the road alarms environmentalists' (O'Connor, 2008). Ratan Tata was reported to have dismissed environmental concerns with the statement: 'We need to think of our masses. Should they be denied the right to an individual form of transport?'

Simon Arron writing for Telegraph.co.uk (Arron, 2009) indicated the Indian-built Tata Nano would be sold in the UK but not before 2012. Displayed at the 2009 Geneva Show the European version will be longer, more powerful, safer and better finished.

As manufacturers put sustainability more firmly on the agenda it is likely that more will explore less complex products with a smaller parts-count and fewer unnecessary 'comforts'. These are likely to appeal to price-conscious consumers who simply want cheap and safe personal transport. The Tata

Nano, though not technically advanced, represents new a niche of properly engineered but inexpensive micro cars that meet current safety standards.

TOYOTA IQ (JAPAN)

The Smart ForTwo emerged from one man's dream to create an entirely new type of car with just two seats that was short enough to park end-on to the kerb. It had its drawbacks, not least of which that it *was* only a two-seater but it introduced a new standard of small-car active and passive safety devices, including stability control. The VW Lupo had four seats but, lacking the technical innovations of the Smart, it was a full metre longer and an entirely conventional supermini.

By contrast the Toyota iQ (Figure 7.6) is a car which answers some of the Smart's criticisms and which is in many ways a genuine spiritual successor to the BMC Mini. With the iQ, Toyota set out to produce the shortest and safest four-seat car possible. This was achieved with a 2985 mm-long car which is just 290 mm longer than the latest Smart ForTwo and amazingly 100 mm shorter than the original BMC Mini yet it achieves a five-star Euro NCAP rating using the latest and more stringent testing regime. All this was possible without resorting to exotic new materials or technical innovations but by very clever packaging.

Figure 7.6 Toyota iQ
Source: Toyota.

The iQ's designers challenged the assumption a small city car must *simultaneously* provide four similar seats and luggage space. Instead they considered how a city car is used in real life and provided flexibility. The iQ is not a 'full 4-seater' by the usual definition. Instead most would describe it as a 3+1 that can transport three 6′ 3″ adults and a child. In normal use two adult front occupants can have lots of room and between 32 litres or 242 litres of luggage capacity depending on whether the rear seats are up or down. The passenger-side dashboard is cut away so the front seat can be moved forwards more than the driver's to accommodate another adult behind. Realistically there is only enough legroom behind the driver for a small child (or luggage) in the fourth seat.

Mechanical packaging is also clever. The iQ is front-engined and in order to push the wheels out as far as possible the differential is placed ahead of the three-cylinder engine. This also moves the engine closer to the cabin, behind the frontal crumple zone, for added safety. The track has been kept as narrow as possible to give the iQ a 3.9 metre turning circle which is less than a Smart ForTwo. A flat and shallow 32-litre fuel tank lies below the passenger floor to save space. To reduce CO^2 emissions the iQ has stop-start technology and low-rolling resistance tyres. It is also very light at just 860 kg unladen. With a 99 g/km carbon dioxide figure the 998 cc iQ is the first petrol car to fall into UK Car Tax band A (tax free).

The Toyota iQ is also the first car to include rear curtain airbags to protect back-seat passengers in the event of the car being rear-ended. In total it has nine airbags. As with the Smart it has a rigid safety cell and stability control and, as a city car that will spend most of its time parked on urban streets, it has also been given very good security in the form of a Thatcham Category 2 alarm and immobilizer.

In summary the iQ shows how even mainstream producers are turning from '4-seat-with-luggage' thinking to include microcars in their offering. With short length as its primary goal the iQ has moved away from the normal symmetrical layout. Certainly it can travel at over 90 mph on a motorway (not its natural habitat) and at 67 mpg its 32-litre fuel tank should give a range of nearly 470 miles but this misses the point. The iQ is small and nippy for town use, should be as easy to park as an original Mini but it is less compromised than a Smart ForTwo. The iQ cannot provide 4 full seats and lots of luggage space *at the same time*. No car under 3 metres long can achieve this and gain five stars at Euro NCAP in 2011. However, the 2985 mm iQ can do *all* of these things for *some* of the time depending upon how it is configured – and that is very new.

RENAULT TWIZY (FRANCE)

The Twizy (Figure 7.7) is the latest microcar from Renault, a company with a strong design heritage and history of establishing new niches. Philosophically similar to voiturettes, the Twizy is an ultra-compact electric runabout marketed as a second car for urban dwellers or as a 'sans permis' version for younger drivers. Closely based on a concept car called the Twizy ZE from Renault Advanced Design studio the production version was created with all the engineering resources of the company.

Overall dimensions are 2.32 m long by 1.19 m wide by 1.46 m high. Driver and passenger sit in tandem with the passenger's legs wrapping around the driver as on a scooter. Both are protected by deformable structures and by the outboard positioning of the wheels. Seatbelts and a driver's airbag are fitted and the Twizy comes as an open-sided vehicle with a broad bar across the door aperture with the option of an additional lower door panel for better weather protection.

The Twizy is planned for sale in Europe at the end of 2011 priced to compete with three-wheeled scooters over which it has many advantages,

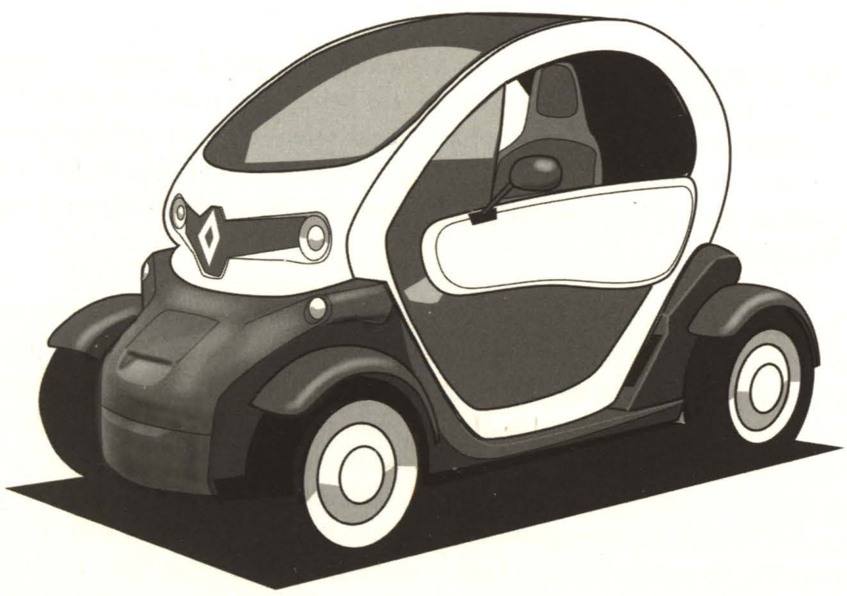


Figure 7.7 Renault Twizy
Source: Author.

not least its car-like controls and the exemption from wearing crash helmets and protective clothing. If successful the Twizy may herald a new class of vehicle which sees other manufacturers clamouring for a share of the market.

Microcars Designed by Engineers and Innovative Individuals

BUBBLE CARS (GERMANY AND ITALY)

The first stimulus for 'modern' microcars cars was the Suez Crisis. In 1956 the Egyptian leader Nasser declared that he was to generate revenue to pay for the Aswan Dam irrigation project by nationalizing the Suez Canal, which linked the Red Sea to the Mediterranean. Tanker ships carried two-thirds of Europe's oil through the canal instead of making a much longer journey around the horn of Africa. The threat to the easy supply of oil resulted in the emergence of a number of small and very economical, but quite crude, bubble cars built in former German aeroplane factories and exported throughout Europe. The most recognizable of these were the BMW Isetta, Heinkel Trojan and Messerschmidt KR (Figure 7.8). France also began to produce so-called voiturettes but these were for domestic consumption only (see below). Bubble car styling was almost incidental since the cars were designed by engineers. Renzo Rivolta was a refrigerator manufacturer who charged two of his engineers Ermenegildo Preti and Pierluigi Raggi with designing a small car for the masses in 1952. Rivolta later licensed the Isetta design to BMW. The Heinkel Trojan and Messerschmidt KR1 were conceived by aircraft designers Fritz Fend and Ernst Heinkel respectively. Both were expert in the use of lightweight materials and glazing and aircraft influences are clearly apparent in the designs.

Figure 7.8 **Bubble cars – Left to right: BMW Isetta, Heinkel Trojan, Messerschmidt KR**

FIAT TOPOLINO AND FIAT 500 (ITALY)

The original Fiat 500 Topolino (Italian for Mickey Mouse) was launched in 1937 (Figure 7.9) and is attributed to Dante Giacosa, FIAT's legendary engineer and designer. Although one of the smallest cars in the world it was advanced for its day and a fully engineered 'real' car. It had a 569 cc water-cooled four-cylinder, side-valve engine mounted at the extreme front with the tall radiator behind. This allowed it to have a raked nose for excellent visibility. Three models were produced and the car remained in production until 1955 with only minor cosmetic changes. Nearly 520,000 were sold.

In 1955 Fiat introduced a small rear engine car called the 600 powered by 633 cc or 767 cc water-cooled four-cylinder engines. In 1957 this was joined by a little brother the Nuova (new) 500 (Figure 7.10). Designed as an economy car, the original Nuova 500 had an air-cooled 2-cylinder engine of just 479 cc. The Fiat 600 remained in production until 1969 but the Nuova 500 went on until 1975. With dimensions of 2.97 m long 1.32 m wide and 1.32 m high, the 500 was marketed as cheap and practical and became one of the first true city cars and many survive to this day.

Like the Mini (on page 220) the enduring styling of the Nuova 500 inspired a latter-day spiritual successor in 2007, the Fiat Nuova 500 (Figure 7.11) designed by Roberto Giolito.

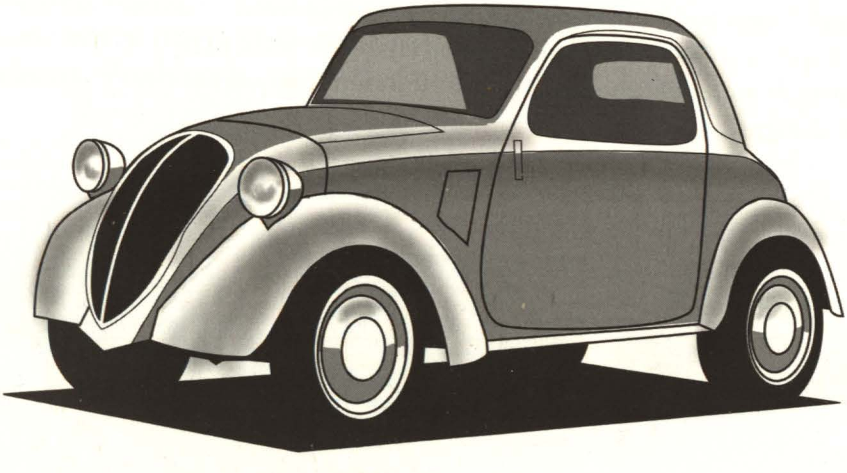


Figure 7.9 Fiat 500 Topolino – 1937
Source: Author.

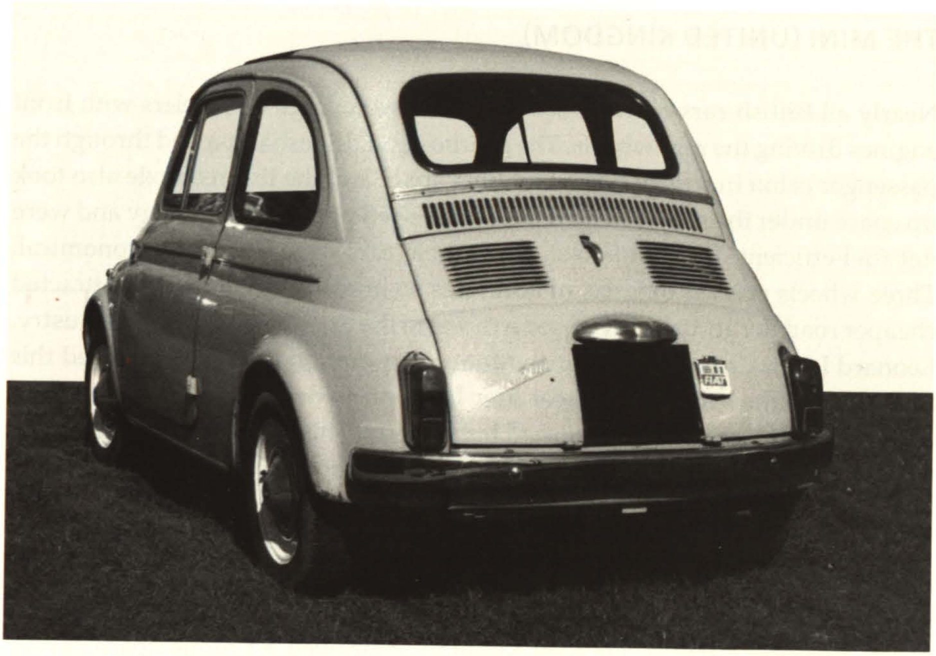


Figure 7.10 Classic Fiat 500 – 1957
Source: Author.

Figure 7.11 Fiat Nuova 500 – 2007
Source: Author.

THE MINI (UNITED KINGDOM)

Nearly all British cars of the 1950s and 1960s were large 4-wheelers with front engines driving the rear wheels. The gearbox and driveshaft passed through the passenger cabin in a deep tunnel robbing space and the live rear axle also took up space under the rear load area. Most cars used pre-war technology and were not fuel-efficient. By comparison the bubble cars were light and economical. Three wheels classed them as motorcycles so in many counties they attracted cheaper road tax and quickly posed a threat to the existing automobile industry. Leonard Lord, Chairman of British Motor Corporation (BMC), recognized this and directed the brilliant engineer Alec Issigonis to design a 'proper' small car to 'see off' the threat of the imported bubble cars. This decision had a huge and far-reaching effect upon the future design of the automobile.

The 1959 Mini (Figure 7.12) introduced many small-car innovations that endure to this day. Not least was the first use of a water-cooled transverse front-wheel-drive arrangement that did not intrude into passenger or luggage space. Issigonis's friend, Dr Alex Moulton, conceived a unique space saving suspension that replaced steel springs with rubber cones. The body was a conventional welded steel monocoque, though with an engineer's eye on ease of manufacture Issigonis designed it with external weld flanges that became such a visual feature of the car.

The Mini was the first serious microcar of the modern era. Daring and innovative in its day its layout has since become the norm in small and medium

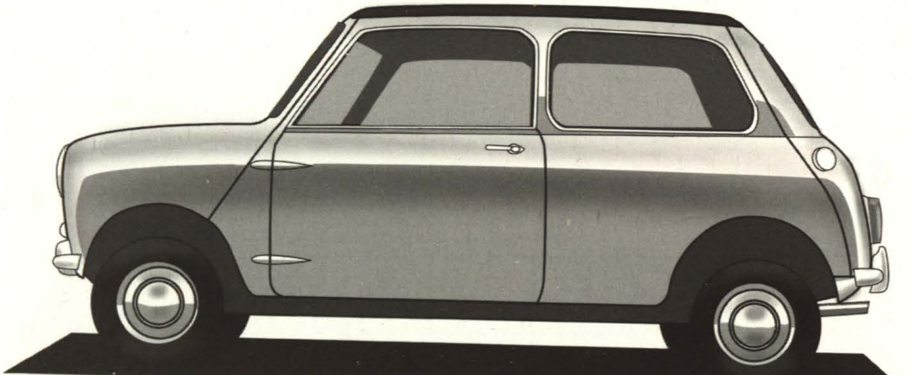


Figure 7.12 BMC Mini – 1959
Source: Author.

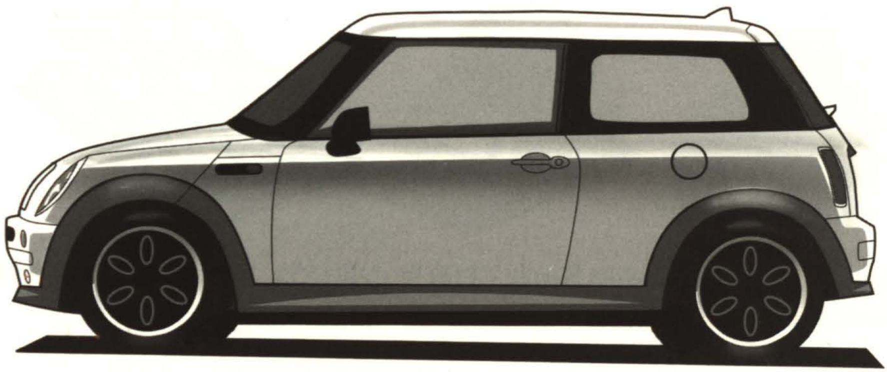


Figure 7.13 2001 Mini One – 2001
Source: Author.

car design and has even been used in larger cars and vehicles (including most light and medium sized vans). Mini set a template for small-car drive train layout that maintains to the current day.

Like Dante Giacosa at Fiat, Issigonis was first and foremost an engineer whose main focus was providing the best technical solution using the most up to date and appropriate technology. However, he also had an innate sense of form and proportion which manifested itself in the visual design of the Mini. The original design was so good that it spawned a number of derivatives and provided the inspiration for Frank Stephenson's spiritual successor which appeared in 2001 (Figure 7.13).

PEEL CARS (ISLE OF MAN)

The Mini was innovative and much smaller than most of its contemporaries but in many ways quite conventional. It had a steel body, four-cylinder four-stroke petrol engine with four-speed manual gearbox, seats for four passengers and it had four wheels! However, there were others wishing to go even smaller using alternative technologies in the manufacture.

In 1963 on the Isle of Man, Peel Engineering, famous for fibreglass motorcycle fairings and boats decided to apply their knowledge of early composites to microcars. They were innovative because the car bodies were true load-bearing GRP monocoques with no separate chassis, a technique first employed by Colin Chapman on the 1960 Lotus Elite.

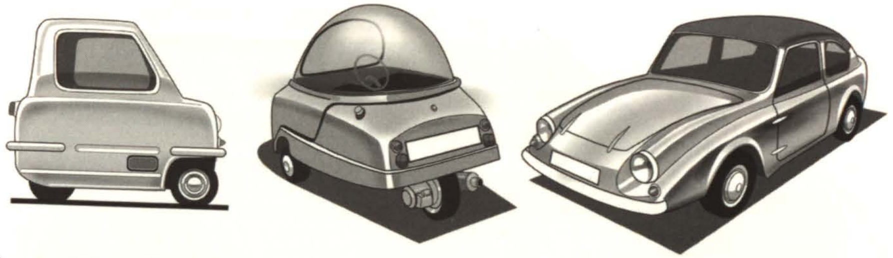


Figure 7.14 Peel Product Range – Left to right: P50, Trident, Viking Sport
Source: Author.

Several Peel models were produced in volume: the P50, the Trident and the Viking Sport (Figure 7.14). Of these, the P50 still holds the record for smallest mass-production car.

Journalist and presenter Jeremy Clarkson famously 'drove' one around the corridors and offices of BBC Television Centre for an episode of *Top Gear*. The P50 followed a downsizing, reductionist philosophy at only 1.34 m long and 1 m wide with a weight of just 59 kg, three wheels, a single headlight and side-mounted DKW 49 cc, 4.2 hp, fan-cooled two-stroke engine driving the rear wheel through a three-speed gearbox. Its top speed of 38 mph sounds perfectly

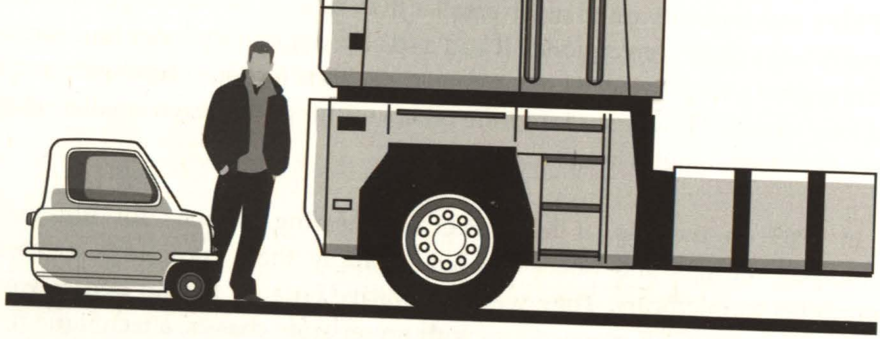


Figure 7.15 Peel P50 and Renault Magnum size comparison
Source: Author.

adequate for modern city traffic (bikeforall.net, 2006) though its diminutive size would sit uncomfortably on the road with some of today's other vehicles. (Figure 7.15)

Sinclair C5 (United Kingdom) – Case Study

The Sinclair C5 (Figure 7.16) is another microcar that deserves mention for having reached full production as the brainchild of a single entrepreneur with the bravery and resources to challenge convention.

(Now Sir) Clive Sinclair is the British electronics entrepreneur who in 1982 brought personal computing to the masses with his ZX Spectrum. However, he had long been fascinated with silent and pollution-free electric vehicles (sinclairc5.com). Sinclair recognized that most electric vehicles were based on internal combustion engine cars with their fuel tanks and engines replaced by

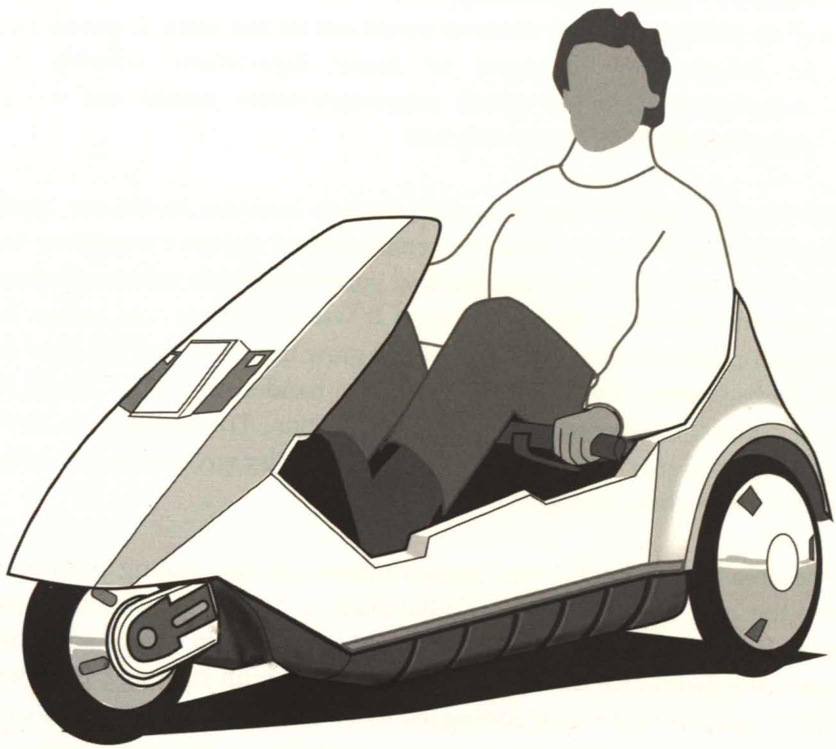


Figure 7.16 Sinclair C5
Source: Author.

electric motors and batteries making them heavy and cumbersome. He strongly believed a truly effective electric vehicle would need to be conceived from the ground up without compromise.

Sinclair began work on a personal electric vehicle in 1979 at his company Sinclair Research. The initial brief was for a vehicle to compete with petrol mopeds, able to carry a single occupant with occasional seating for a second, and a top speed of 30 mph. Sinclair envisaged sales of 100,000 units per year. During 1980s the specification began to change and become more focused:

> *It was to carry the housewife, the urban commuter or the youngster; its advantages over the moped would be that it offered greater safety, weather protection, economy – and style – at a competitive target price of £500. It would be designed to be easy to drive, easy to park, easy to get into and out of, and easy to load. It would need minimum maintenance and would provide maximum power efficiency for minimum battery size. For urban performance, it should have a minimum range of 30 miles on a fully charged battery, which could be extended by means of an additional battery. Batteries would last for two years. It would be designed and engineered for simple, high-volume assembly using injection-moulded plastic components where possible and a polypropylene body. (sinclairC5.com)*

In 1983 Sinclair sold his shares in the research business to finance Sinclair Vehicles Limited. The new company commissioned design consultancy Ogle to style and production engineer the new personal electric vehicle. However, Ogle appeared to tackle the project as if it was an electric 'car' rather than building on cycle technology and the weight grew from less than 100 kg to over 150 kg. Subsequently development work was handed to Lotus Cars to take the new vehicle, christened C5, to final production. The styling was revised by a product designer called Gus Desbarats, who later went on to a successful career in mobile phone design.

One area where the C5 was compromised was the seating position. To remove the cost of providing seat adjustment a fixed seat was designed to accommodate people from small 14-year-old female up to a large adult male. This gave the distinctive recumbent riding position with steering bars beneath the rider's knees. Wind tunnel testing led to a low drag shape but the low nose only left room for very short cranks to the pedals.

The C5 was powered by a dedicated motor made in Italy by Polymotor mated to a Lotus designed gearbox. Sinclair chose to use tried and tested existing technology. Ordinary car batteries were unsuitable for use in traction applications so Oldham batteries in Manchester developed a new 'deep discharge' battery for the C5 with an effective life in excess of 300 charge and discharge cycles.

One of Sinclair's real innovations was to look beyond the automobile industry for manufacturing expertise. The C5 bodywork comprised two large injection mouldings in recyclable polypropylene. The upper part remains one of the largest single piece injection mouldings ever produced. The two halves were fuse-welded under pressure using electrically heated tape borrowing technology from the 1977 Topper Dinghy.

Recognizing that the C5 was closer in construction to domestic appliances than motor cars Sinclair subcontracted the final assembly to Hoover at their Merthyr Tydfil plant in Wales giving Sinclair access to Hoover's network of 19 service centres across the UK. Four hundred Hoover service engineers were trained to carry out C5 maintenance in the home just as they would for washing machines.

In January 1985, the C5 was made available by mail order direct from Sinclair Vehicles and by summer 1985 could be bought from Comet electrical retailers. Three hundred Comet outlets and a number of Woolworth stores were also established as Sinclair battery centres to supply new and replacement batteries and chargers and to deal with any warranty issues.

Unfortunately the Sinclair C5 did not sell. The C5 was extremely advanced and was as small as was feasibly possible to reduce weight and cost, but unfortunately cost-cutting was its undoing. Many of those involved in the project had driven the C5 on the test track, blinkered by its performance. But on the open road it suddenly dawned on people just how vulnerable the C5 was. Being relatively slow and so low to the ground it was almost invisible to other road users. Some users did not appreciate they would have to pedal the vehicle occasionally to conserve or supplement battery power or to get home should it run flat. Cold weather also severely affected battery range and although a fully charged spare could be carried to swap over this was an inconvenient solution. The cost-saving 'one-size-fits-all' recumbent riding position with its under-knee steering yoke was not conducive to efficient pedalling, a situation made worse by inappropriate gearing and short pedal cranks. More importantly buyers immediately began to question the safety of such a tiny vehicle on busy urban streets. Ironically there had been a plan to fit every C5 with a high-level indicator bar with light and reflector but this was only offered as a cost option to keep the basic C5 below a £400 price point. This simple addition would have made the C5 far more conspicuous and may have been the difference between success and failure.

Newspaper cartoonists and comedians savagely ridiculed the C5 and tarnished its image to the extent that sales collapsed. The C5 became a commercial disaster and the Hoover Factory ceased C5 production on 13 August 1985 with fewer than 12,000 sold. Sinclair Vehicles itself went into receivership on 12 October 1985 just nine months after the C5 went on sale.

In summary, Clive Sinclair's vision was worthy but perhaps 30 years before its time. Oil was still cheap and environmental awareness in its infancy. There were few dedicated cycle lanes available but now there is provision for cyclists and city speeds are so low that small electric vehicles are beginning to appeal once more. Battery technology has also moved on apace and even lighter construction techniques and materials are available. However, the original C5 was still ergonomically flawed and it is unlikely that a spiritual successor would be designed the same way. Perhaps the real tragedy of the C5 is that it was seen as just the first and smallest of a series of pollution-free electric vehicles that would be developed by Sinclair Vehicles up to the end of the 1990s. Had the C5 been a success in 1985 then we might all be driving its progeny today and with 25 years of development and Sir Clive Sinclair's genius they would probably be very good.

VOITURETTES (FRANCE)

The heyday of microcars and cyclecars was during the 1950s when Italy and Germany built 'bubble cars' for export all around Europe but by the start of the 1960s the demand had waned as mainstream car manufacturers began to build small affordable 'real' cars (Figure 7.17). Volkswagen's Beetle and Fiat's 500 were small air-cooled rear engine cars and in 1963 in Britain, Rootes Group also built the Hillman Imp following the same space efficient rear-engined formula but using a water-cooled all-aluminium engine which was very advanced for the day. The microcars fell out of favour rapidly but elsewhere others were probing the boundaries of the motoring laws. In the mid-1970s a number of French companies decided to resurrect the voiturette concept to exploit a loophole in French road laws which permitted cars be driven without a licence (sans permis) subject to a number of size, power and weight restrictions.

Figure 7.17 Volkswagen Beetle, Fiat 500, Hillman Imp
Source: Author.

One such manufacturer was French engineer and entrepreneur Daniel Renard. In 1976 he established a new company, Societe Etudes et Realization Automobiles Du Douasis (ERAD), to build new voiturettes. Rival companies followed including Ligier (with links to the Formula 1 team) and Arola (changed to Aixam in 1986). Renard was the most forward-thinking and employed new technology in manufacture. Whereas most of his competitors used GRP techniques from boat building, ERAD adopted vacuum-forming to mass-produce thermoplastic body panels riveted onto tubular steel chassis with plywood floor panels. Consequently his cars could be built in higher volumes. Renard also began to develop a range of micro utility vehicles which were perfect for cities such as Paris with its pedestrian boulevards.

In the mid-1980s Renard targeted younger drivers with a small, funky car called the Junior that had a jet-fighter-style upward-hinged canopy. By 1988 automotive styling had become more sophisticated and his old production technique of vacuum-formed panels onto metal frame was restricting what was possible. So in 1989 ERAD commissioned UK-based design consultancy Styling International Ltd to design a new car with no visible framework but still using ERADs construction methods. The end result was an attractive little mono-volume car, the 'Spacia', that was in production by 1990, some three years before the similarly shaped Renault Twingo. The exterior was styled by Jonathan Gould and the interior by the author who was also closely involved with production design of the Spacia in France. The Spacia vacuum formed body panels required some complex 3-D trimming and with characteristic forward-thinking Renard invested in CNC milling equipment to cut the panels quickly and accurately. Used ERAD Spacias can still be found for sale in France and other European countries.

During the late 1990s Renard sold the ERAD brand and established a new company SECMA (Societéd'Etudeet de Construction Automobile) which still produces a wide range of small diesel and electric powered micro vehicles in the same factory in Aniche (SECMAvehicule.com). Many of these are aimed at younger buyers. Some products are now sold in the UK.

QUADRICYCLES (PAN EUROPE)

In the context of this chapter the term quadricycle relates to two classes of motorized vehicles defined by European Regulations, Framework Directive 2002/24/EC. This legislation covers quad bikes and certain types of four-wheeled microcar or voiturette (Figure 7.18). These quadricycles can be sold across Europe and legally driven on the road. The two categories are defined as light and heavy.

Light Quadricycles (UKQIA.org) must not exceed 350 kg unladen (which excludes the mass of batteries in the case of electric vehicles) and are restricted to 45 km/h. Engine capacity and power restrictions also apply. (Light quadricycles are classified with some mopeds so they can be driven without a licence in France, Italy, Belgium and the Netherlands.)

Heavy Quadricycles (UKQIA.org), normally associated with road legal quad bikes, must not exceed 400 kg unladen for passenger vehicles or 550 kg unladen for vehicles intended for carrying goods (again excluding the mass of batteries in the case of electric vehicles). Top speed is not limited but net engine power is restricted to 15 kW (20 bhp). Heavy quadricycles are classified with motor tricycles in Europe so they can be driven on a motorcycle licence (though not in the UK where different rules apply to all four-wheelers).

Microcars classed as quadricycles (Microcar.com) offer a lightweight and fuel-efficient alternative to full-size motor cars but modern 'real' cars are stronger and stiffer and incorporate more passive and active safety systems to protect their occupants and pedestrians. In a collision between a car and a

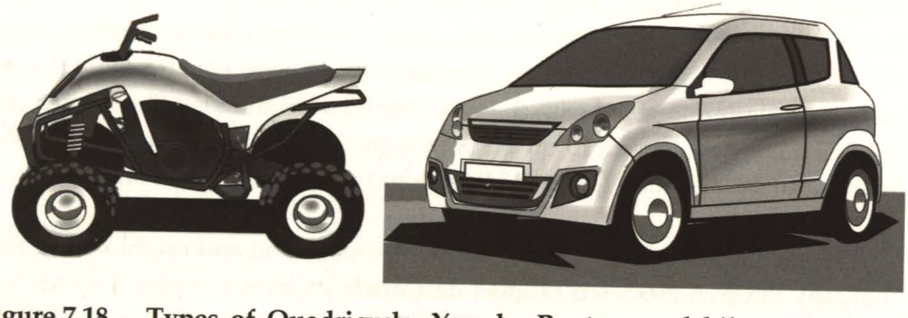


Figure 7.18 Types of Quadricycle: Yamaha Raptor quad bike and Aixam Microcar

Source: Author.

quadricycle the much cruder lightweight vehicle is likely to come off worse. The Aixam Crossline microcar sold in the UK is derestricted and can reach a claimed 70 mph (Aixam.co.uk). Although they look like small cars, and can travel almost as fast, quadricyle microcars are not subject to the same occupant safety and collision performance legislation as the 'real' cars with which they share road space which could make them potentially less safe.

PERAVES ECOMOBILE AND MONOTRACER 'CABIN MOTORCYCLES' (SWITZERLAND)

The Peraves Ecomobile (Figure 7.19) was the original tandem-seated 'feet forwards' enclosed motorcycle (or cabin motorcycle) designed and built in Switzerland by another engineer, Arnold Wagner of Peraves. Built from 1987 to 2005 the Ecomobile is a rare sight due to its expense.

The Ecomobile's successor is called the Monotracer (Figure 7.20) and is powered by BMW K1200 drivetrain with 130 hp and a top speed of 155 mph. A 14-gallon fuel tank and fuel consumption of 47 mpg at 75 mph give it a range of just over 650 miles between fuel stops. The body is made from lightweight Kevlar, glass and carbon composite bonded with epoxy resin on a tubular aluminium reinforcing structure. The cabin is heated and air-conditioned.

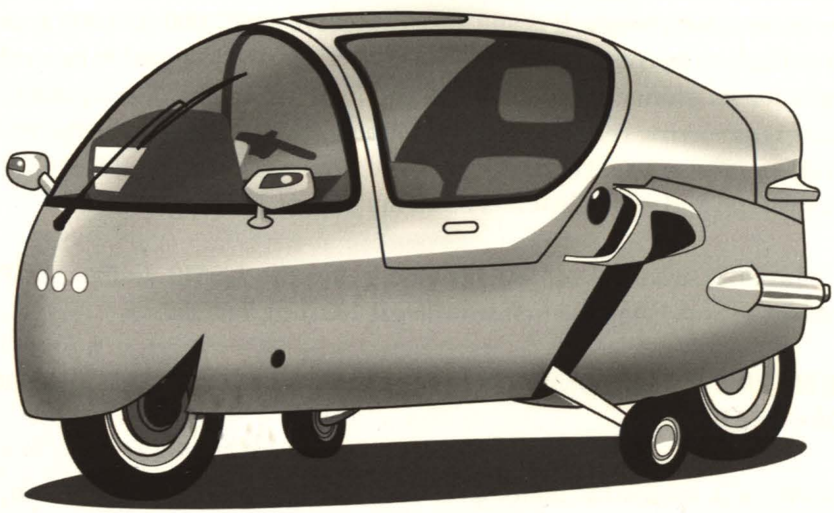


Figure 7.19 Peraves Ecomobile
Source: Author.

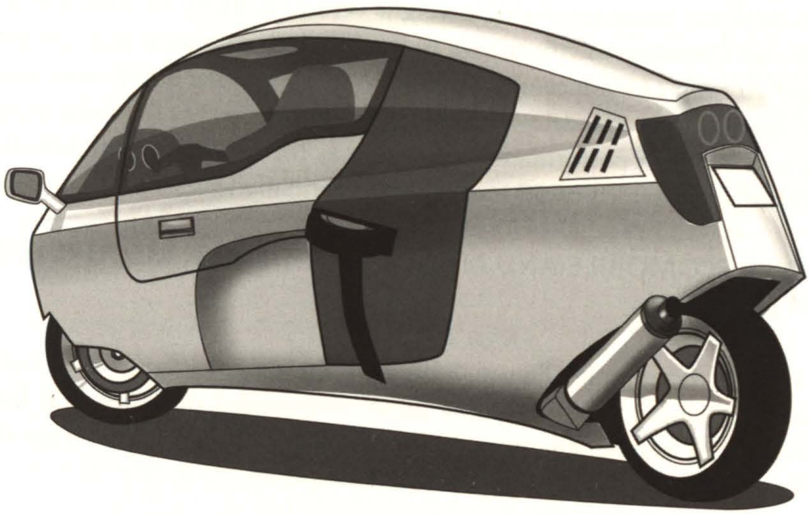


Figure 7.20 Peraves Monotracer
Source: Author.

Since the driver's feet are enclosed all Peraves cabin motorcycles have computer controlled stabilizing wheels which deploy from its flanks when the vehicle is slowing, stationary or reversing. Controls are the same as a motorcycle with handlebars rather than a steering wheel. The original Ecomobile was cigar-shaped but the Monotracer has a more refined form which is also claimed to be more aerodynamic. It is still very expensive at €52,000 (£42,000 approx.) so is unlikely to be common on the roads nor is it really designed to be a vehicle bought for its economy though other products are under development. The eTracer is an electric version of the Monotracer and is claimed to be the world's fastest and most efficient high-performance two-seater vehicle with a top speed over 150 mph and equivalent fuel economy of over 200 mpg.

Peraves is also an official contender for the US$10 million *'X-Prize'* competition to develop the first street legal 100 mpg vehicle.

THE NARROW CAR COMPANY (PRODRIVE) NARO (UNITED KINGDOM 2004 – PRESENT)

Prodrive is a successful motorsport and automotive engineering company that has been involved in many areas of motor sport since 1984 as well as many road-car-design, engineering and manufacturing projects for various automotive manufacturers.

Figure 7.21 Prodrive NARO Coventry Concepts
Source: The Narrow Car Company [left and right] and Coventry University archives [centre].

NARO is an ongoing project begun in 2004 which stemmed from Prodrive's own research into a 4-wheeled 'free leaning' tilting vehicle designed to offer the stability, comfort and safety benefits of a normal car with the narrowness, agility and economy of a two-wheeled motorcycle. Efficiency and low emissions were also important requirements of its brief. The unusual thing about NARO is its proportions. Although not much longer or wider than a motorbike with panniers the NARO is as tall as a conventional MPV. This makes it much more conspicuous to other road users and gives the driver excellent visibility. Being so slim it can take advantage of gaps in traffic much like a two-wheeler.

Initial concept and styling work was undertaken with the Industrial Design Department of Coventry School of Art and Design early in 2004 (Figure 7.21).

In late 2004 the rights to the NARO concept were transferred to a new company 'The Narrow Car Company' established in Wales by Prodrive's former Engineering Director Hugh Kemp (www.naro.co.uk). Further engineering prototyping is ongoing with Swansea Institute School of Mechanical Engineering. The NARO is powered by a 400 cc single-cylinder, 4-valve, 20bhp petrol engine driving through an automatic CVT gearbox. Overall dimensions are 2.5 m long by 1.0 m wide by 1.7 m high with a dry weight of 300 kg. Designed for practical, economical transportation rather than sportiness it has a claimed 0–60 mph time of 12 seconds, top speed of 85 mph and fuel consumption of 100 mpg. The *'free leaning'* system does not rely on complex electronics. Instead the suspension and steering geometry induces the appropriate amount of lean to counteract the cornering forces. Several versions have been proposed including an executive commuting vehicle, taxi and urban delivery vehicle. The NARO website (www.naro.co.uk) reports the project is ongoing and current development is looking at alternative drive-trains including battery electric and fuel cell using electric wheel motors.

Interestingly the Renault Twizy is similar in concept to the NARO but is far simpler without the complex tilting system. Its electric drive train and batteries give it a very low centre of gravity so the need to tilt is unnecessary. Dimensionally the Twizy is 180 mm shorter, 190 mm wider and 240 mm lower so they are very closely matched. Given that it will sell for about the price of a three-wheeled scooter the production ready Twizy is bound to be a threat to the NARO which is still some way from production.

COMMUTER CARS CORPORATION 'TANGO' (USA)

One of the strangest microcars on sale today is the 'Tango' (Figure 7.22). Its manufacturers, Commuter Cars Corporation of Spokane in the state of Washington, claim the Tango 'combines the speed and agility of a motorcycle with the security of a high-performance sports car'. Indeed the performance figures speak for themselves. The twin motor Tango can accelerate to 1/4 mile in 12 seconds reaching over 120 mph – and accelerate from 0 to 60 mph in

Figure 7.22 Commuter Cars Tango
Source: Author.

4 seconds. Top speed is quoted at 135 mph. The Tango reputedly beat the Tesla Roadster and Shelby Cobra in separate drag races, as well as several Corvettes in an autocross.

Different battery options are offered to give an operating range 40–60 miles with lead-acid or over 150 miles with Li-Ion. Driver and passenger sit in tandem in racing bucket seats with four-point harnesses. On paper it is hard to fault the claims but the problem with the Tango is its proportions. At 2565 mm long by 990 mm wide by 1524 mm tall the Tango has dimensions strikingly similar to the Prodrive NARO and Renault Twizy but unlike the others the styling has not been optimized to mask these proportions or to give it a unique aesthetic. The Tango seems to be too tall and narrow for its length and purpose. It is very stable under high-speed cornering on account of heavy batteries giving it a very low centre of gravity but ironically it doesn't *look* stable. Worst of all it has normal-width front and rear car lamps set in an extremely narrow mask so it looks like a 1980s city car that has been squeezed laterally. The Tango has the physical appearance of a piranha fish.

British automotive engineering consultancy Prodrive carried out work in 2005 to refine the design and engineering of the Tango. In January 2010 (Clark, 2010) it was reported that 11 'T600' Tangos had so far been sold to customers at a price of US$150,000 (£90,000), one to a UK customer in Surrey. The T600 is the luxury version of the Tango with a carbon-fibre body but there are plans for cheaper versions with fibreglass bodywork and lower drivetrain specification called the T200 and T100. Strangely for a £90,000 car the Commuter Cars Corporation website states that the T600 is supplied as 'a mostly assembled kit making completion by any customer a quick and easy task'. Batteries and drivetrain are '*not included*'.

GOINGREEN G-WIZ (UNITED KINGDOM – MANUFACTURED IN INDIA)

The GoinGreen G-Wiz (Figure 7.23) is another microcar that emerged from the vision of a single-minded engineer, Californian Dr Lon Bell, who became interested in the idea of a minimalist electric vehicle in the early 1990s. To make this a reality Bell established a joint venture between his own US based company AEV LLC and the Indian manufacturing conglomerate Maini Group to form Reva Electric Car Company in 1994 in Bangalore (GoinGreen.co.uk). The Reva electric microcar was launched in Bangalore in 2001 and then three years later in London as the G-Wiz where GoinGreen was established with the aim of marketing the G-Wiz as a serious alternative to conventional cars for

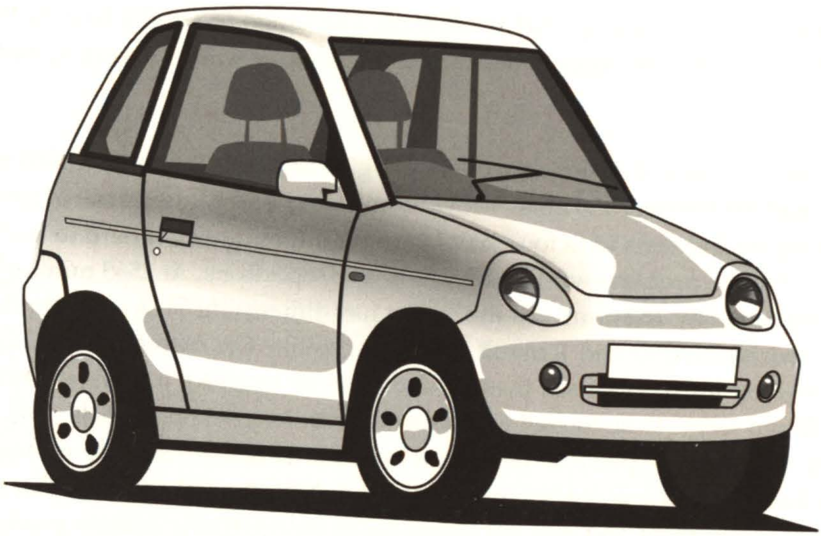


Figure 7.23 GoinGreen (Reva) G-WIZ
Source: Author.

urban commuting in the city. Within two years the G-Wiz became the world's best-selling Electric Vehicle and made London the 'electric vehicle capital of the world' (GoinGreen.co.uk).

GoinGreen's stated social purpose is 'to encourage responsible driving. In particular, it is to minimize the effects of climate change and pollution from motoring and to bring about safer roads for all road users'. To achieve this, the company had to make its cars cheap enough to compete with existing traditional city cars. GoinGreen claims that before the G-Wiz other electric vehicles cost twice as much as internal combustion city cars. GoinGreen was able to halve the price by a novel approach to marketing. Instead of expensive showrooms and advertising the G-Wiz is sold directly to customers online using what the company describes as 'word of mouth and mouse'. GoinGreen does not employ salesmen but offers incentives like cheaper servicing to existing owners who introduce new buyers. It also claims most test drives are offered by existing customers in their own cars. GoinGreen also offers on-site servicing where its employees will maintain the car at the owner's home or workplace.

In terms of design and construction the G-Wiz bears close similarity to the French voiturettes of the 1980s. Designed in California and manufactured by Reva Electric Car Company in India it has a tubular steel structural space frame with self-coloured vacuum formed ABS plastic panels. To keep costs down it uses traditional 'wet' lead-acid batteries which must be topped up with de-ionised water every three to four weeks. The batteries are expected to last two years before complete replacement at a cost of just over £2,000. Charging takes eight hours from a standard 13-amp plug but 80 per cent of charge can be achieved in 2.5 hours. A full charge will give the G-Wiz a range of up to 48 miles (typically 30–40 miles in normal road conditions, depending on driving style, weather and so on), and a top speed of 50 mph (GoinGreen.co.uk). GoinGreen claims that typical G-Wiz journeys are just six miles long at an average speed of 10 mph and specifically recommends that the G-Wiz should *not* be used on motorways or fast roads.

The G-Wiz is classed as a heavy quadricycle and has full EU Type Approval. GoinGreen argues that EuroNCAP testing is inappropriate to the type and defends the lack of safety features such as airbags and antilock brakes on the strength of the G-Wiz being intended as a low-speed urban car which is driven more defensively. Actual figures would appear to support their argument that the car is perfectly fit for purpose. Department of Transport data showed that in 2005 there were 28,954 serious injuries and 3,201 fatalities on the roads in the UK but since its UK introduction in 2002 the G-Wiz had not been reported in any such incidents.

In London the G-Wiz is exempt from congestion charging and parking is free in pay and display zones. The company claims this could represent a saving of £9,000 per year in certain boroughs. The G-Wiz is also claimed to be the cleanest vehicle on the UK's roads and the least expensive vehicle to own, with lifetime costs lower than any other.

In May 2010 Indian Automotive giant Mahindra and Mahindra took a 52 per cent controlling stake in Reva with a new capital injection of £69.4 million and a claim that the new group, Mahindra Reva Electric Vehicle, will be one of the largest global players in electrical vehicles. Lon Bell, the original designer of the Reva G-Wiz, will remain on the board (Charlesworth, 2010).

THINK CITY (NORWAY)

The 'Think City' (Figure 7.24) is conceptually similar to the G-Wiz but its engineering is far more sophisticated and it is more powerful with advanced sodium or lithium batteries and greater range. However, it is also nearly twice the cost of the G-Wiz and the charging time is longer.

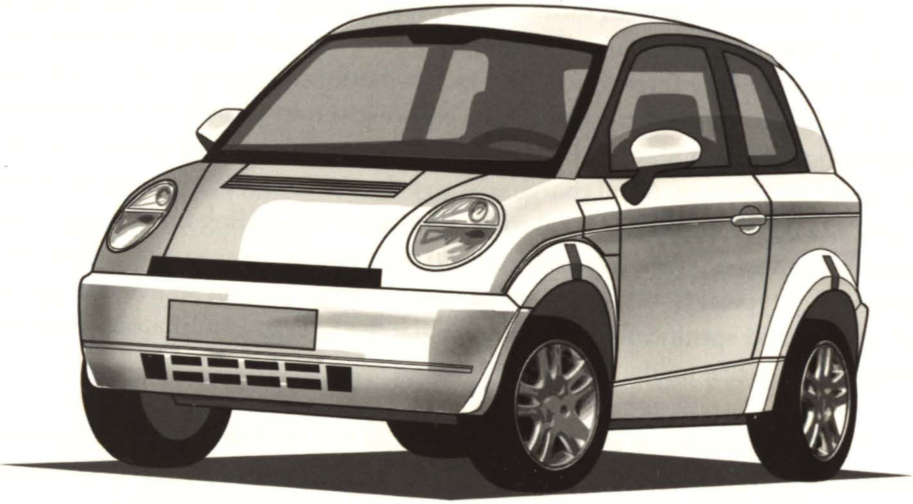


Figure 7.24 Think City – 2009
Source: Author.

The original Think City prototype was developed by its Norwegian founders in 1991 with ABS bodywork on a steel chassis. In 1999 the first generation 'Think City' was put into production and attracted Ford Motor Company as a major shareholder. Ford invested US$150 million over the next four years which helped pay for the engineering and safety development. Unlike the G-Wiz the Think City is designed for urban and highway use so safety has been a key priority for the vehicle which boasts dual airbags and seatbelt system with pre-tensioners.

In 2003 Ford prematurely lost interest in electric vehicles and sold the company. Think was bought by Norwegian investors in 2006 who went forward to produce the fifth generation Think City which is now on sale in Norway, Austria and the Netherlands. On 1 May 2009 the Think City became the first electric vehicle to gain a pan-European homologation certificate. It can now be registered in each European member state without additional national tests or approvals and Think has plans to expand sales across Europe to meet the demand for electric city cars.

The main drawback of the Think City remains its cost. *Autocar* concluded that even with the cost savings you'll make on fuel, parking, congestion and tax, the Think City is an expensive car (autocar.co.uk, 2008). In addition to a UK price of £14,000, *Autocar* reported owners would have to pay £140 per month for a 'mobility pack' which covers replacement of the expensive battery if it goes wrong or wears out. Think will use telematics to monitor cars by Global Positioning System (GPS) and the mobile phone network (GPRS). This contrasts sharply with GoinGreen's philosophy to keep costs down through simplicity (though even its new cars now retail for between £10,000 and £13,000).

Comparing the two, if GoinGreen's G-Wiz user data is to be believed the Think may be over-engineered for its real purpose. The additional weight of safety equipment may be offset by lighter and more efficient batteries but these in turn will use more exotic materials so their life and recyclability may come into question. Think is more modern in appearance but at twice the price of the G-Wiz it was still described as being 'like an ordinary, if slightly crude supermini'. Think may be 'green' but it also seems like poor value for money alongside its established competition.

GORDON MURRAY DESIGN T25 AND T27 (UNITED KINGDOM)

Gordon Murray is another single-minded engineer with a vision for the future of personal transport. It seems ironic that someone more closely associated with the fast and furious world of Formula 1 motor racing, and the designer of what was for many years the world's fastest road Car (the 1992 McLaren F1) should turn his attention to a vehicle at completely the opposite end of the spectrum but then the principles of racing car design are well suited to the task.

Gordon Murray was born in Durban South Africa in 1946 where he designed, built and raced his own car during 1967 and 1968 (gordonmurray design.com [1]). He came to England in 1969 to find success as technical Director for Brabham winning two world championships in 1981 and 1983. In 1988 he moved to McLaren International as Technical Director where the team won three consecutive championships in 1988, 1989 and 1990. With 50 grand prix wins to his credit Murray left racing in 1991 to establish a road car division, McLaren Cars Limited. Here he was responsible for creating the McLaren F1 road car and later the McLaren Mercedes SLR. The mid-engine F1 supercar, for a time the world's fastest production car, demonstrated Murray's skill in packaging and weight reduction (Figure 7.25). It could seat three in relative comfort, had usable luggage space in its flanks and yet was dwarfed by some its supercar contemporaries. With bodywork designed by Peter Stevens the F1 was also a very strong and safe car. Practical thinking went hand in hand with performance and innovation. Even so the F1 was

Figure 7.25 McLaren F1 – 1992
Source: Courtesy of Gordon Murray Design.

not a soft road car; a racing version won its class at Le Mans in 1995 and two world sports car championships. Murray was also responsible for another unusual sports car, the small tandem 2-seater Light Car Company Rocket from 1991 with styling influenced by 1960s Vanwall formula one cars.

In 2005 Murray set up his own company, Gordon Murray Design Limited, with a radically new agenda. He decided to turn his skill to creating a small, innovatively packaged city car even smaller than the Smart ForTwo but no less safe and with three seats. The car was christened the T25 (Figure 7.26). Not only innovative in its layout and packaging but the entire manufacturing process was planned to be as sustainable as possible.

Ambitious goals have been set for the T25. It will have innovative architecture and flexible interior layout to support a variety of uses. It is so compact that two T25s could travel in one UK motorway lane and three T25s can easily fit into a standard UK parallel parking space end-on to the kerb. Lightweight and optimized structure will allow the car to achieve at least four-star Euro NCAP rating yet it will have a better power-to-weight ratio than the average 2-litre luxury saloon. Accident repair costs will be kept low by using replaceable body panels.

Figure 7.26 Gordon Murray Design T25
Source: Courtesy of Gordon Murray Design.

Murray has also considered the whole 'cradle-to-grave' life-cycle of the vehicle with a view to reducing CO^2 emissions in manufacture. The T25 aims to be best in class for CO^2 emissions and with fuel consumption less than half of the UK average. Smaller size and parts reduction, making some components multi-functional, should reduce the energy used in raw material extraction, tooling and manufacture. Murray claims that recycled materials will be used where possible to have the lowest life cycle impact that meets design requirements. The compact size of the car should also require a smaller factory for final assembly and manufacture.

Other novelties include the idea of 'flat packing' the T25 chassis during transportation enabling 12 times as many T25 bodies to be shipped in a standard shipping container as compared to an average car 'body-in-white'. Even after assembly more vehicles can be transported in the same space required for conventional cars. Light weight should also prolong the life of tyres, one of the most troublesome parts to recycle, and at the end-of-life, the choice of materials will ensure that many components will be re-usable including the body and chassis.

As with the McLaren F1 the T25 adopts a central driving position which it is claimed allows six internal layouts within the same vehicle, each layout being easily achieved within 30 seconds. And like the F1 the car can carry three 97.5 percentile males in comfort. With driver-only the car can offer 750 litres of luggage space. As with the Toyota iQ, the T25 is one of a new generation of microcars that eschews the traditional 4-seats layout in favour of a design solution fitter for the purpose of real world car usage. It is powered by a 600 cc 3-cylinder petrol engine.

In November 2009 the petrol T25 was joined by a new electric derivative, the T27 being developed jointly by Gordon Murray Design and Midlands-based Zytek Automotive Technology (gordonmurraydesign.com [2]). As with the Smart ForTwo development two decades earlier the greatest hurdle to be overcome by the Murray cars is meeting current safety legislation. In early January 2011 an electric T27 prototype passed the EEC 40 per cent frontal offset barrier test at MIRA with zero cabin intrusion (carmagazine.co.uk, 2011) taking the T25 and T27 project one significant step nearer to production.

TOYOTA PERSONAL MOBILITY CONCEPTS (I-UNIT, I-SWING, I-FOOT, I-REAL) (JAPAN)

Toyota has been at the forefront of personal vehicle future thinking and the impact of telematics since 2004. This crossed over into parallel developments in Toyota Robot Research. Several Personal Mobility concept vehicles were displayed at EXPO 2005 AICHI, JAPAN. These included 'i-unit', a leaf-inspired 4-wheel device which enclosed a single seat in an exoskeletal frame. It could transform from tall and upright for use on pavements to long, low and car-like for the road. The i-swing was a conceptually similar 3-wheeler which could turn within its own footprint. In addition the i-swing could raise onto two gyroscopically stabilized wheels like a Segway HT (see page 243) or become longer and lower for better stability at speed on three wheels. The third, less practical, vehicle was 'i-foot'. Its seating position looked similar to the i-swing except the wheels were replaced by a bi-ped chassis (Figure 7.27). The i-swing could walk on its two legs but was not a robot; the occupant was in control of its direction using joysticks.

Although the first three concepts were quite fanciful the last version called the 'i-REAL' is a toned-down and realistic proposal for a one person vehicle that began to be trialled at the Central Japan International Airport near Nagoya on Saturday 27 June 2009 (Figure 7.28). Four 'i-REAL' single-seat personal

Figure 7.27 Toyota i-foot

Source: Author.

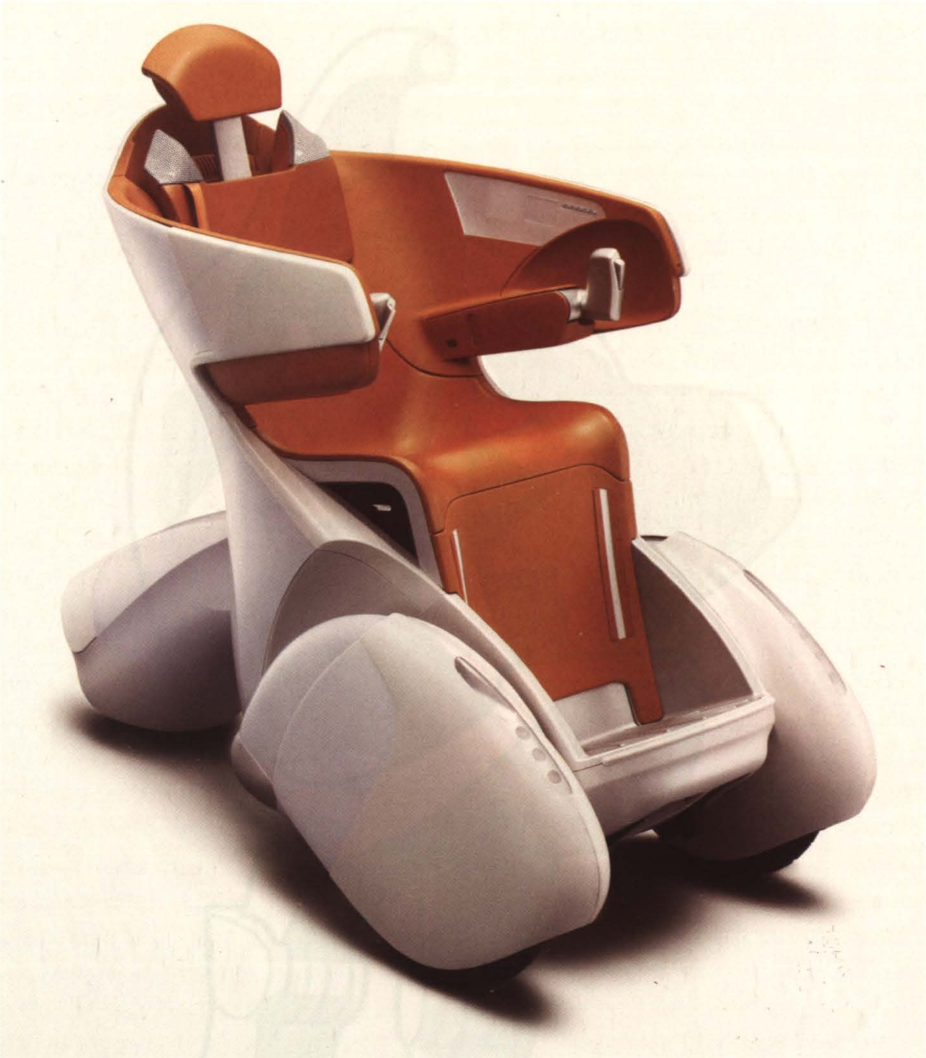


Figure 7.28 Toyota i-REAL
Source: Courtesy Toyota/CarDesignNews (Press Release Photo).

mobility cars were provided by Toyota. Three for use by security patrols and the fourth for visitor assistance and first aid – it carries a computer allowing the public to check flight schedules and a portable defibrillator for medical emergency. The i-REAL usually runs at a speed of about 6 km/h but can achieve 15 km/h in an emergency. It has a range of 30 km on a single charge of its lithium-ion batteries.

SEGWAY HT (HUMAN TRANSPORTER)

The Segway HT is a personal electric vehicle with a history similar to the Sinclair C5 in being the brainchild of an entrepreneurial inventor whose interests lie outside the motor industry. Dean Kamen is a prolific American inventor and engineer and the founder of his own research company DEKA which specializes in medical inventions.

Although Kamen had an interest in the future of transportation this was not his primary goal. The Segway was actually a spin-off from a DEKA project to design a self-balancing wheelchair called iBot which allows users to climb stairs and raise themselves upright. This product was developed with Johnson and Johnson and in June 1999 a new company was formed, Independence Technology LLC (independencenow.com), to develop and market the iBot Mobility System. This company stopped selling and marketing the iBOT Mobility System in December 2008.

Whilst working on the iBot Dean Kamen recognized that its balancing technology could be applied to personal transportation systems for able-bodied users and formed a new company in July 1999 called Across LLC to develop a new product. The company changed its name to Segway in December 2001 and the product became the first-generation Segway HT (Human Transporter) (Figure 7.29). The name 'Segway' was derived from the word 'segue' (pronounced segway), which means 'to transition smoothly from one state to another' which is effectively what the HT does as it moves from static to dynamic modes.

The original version resembled a rectangular platform sitting between two wheels with a T-shaped steering handlebar for control. The Segway HT uses electric motors and a computer controlled gyroscopic stability system to balance. The rider stands on the platform and leans forwards or backwards in the direction he wished to travel. As his mass moves outside the centre of gravity the Segway HT travels in that direction to maintain equilibrium. Turning the handle bar caused the vehicle to steer by differentiating the speed of each wheel. The second generation of Segway HT, now called PT (Personal Transporter) introduced a refinement of the steering system called 'Lean Steer™'. Now the rider steers intuitively by leaning with the lever into the direction of turn. Braking is achieved by the rider leaning backwards. Ordinary friction brakes would have nothing to react against so the Segway PT uses regenerative braking. Under deceleration the traction motors become generators to channel

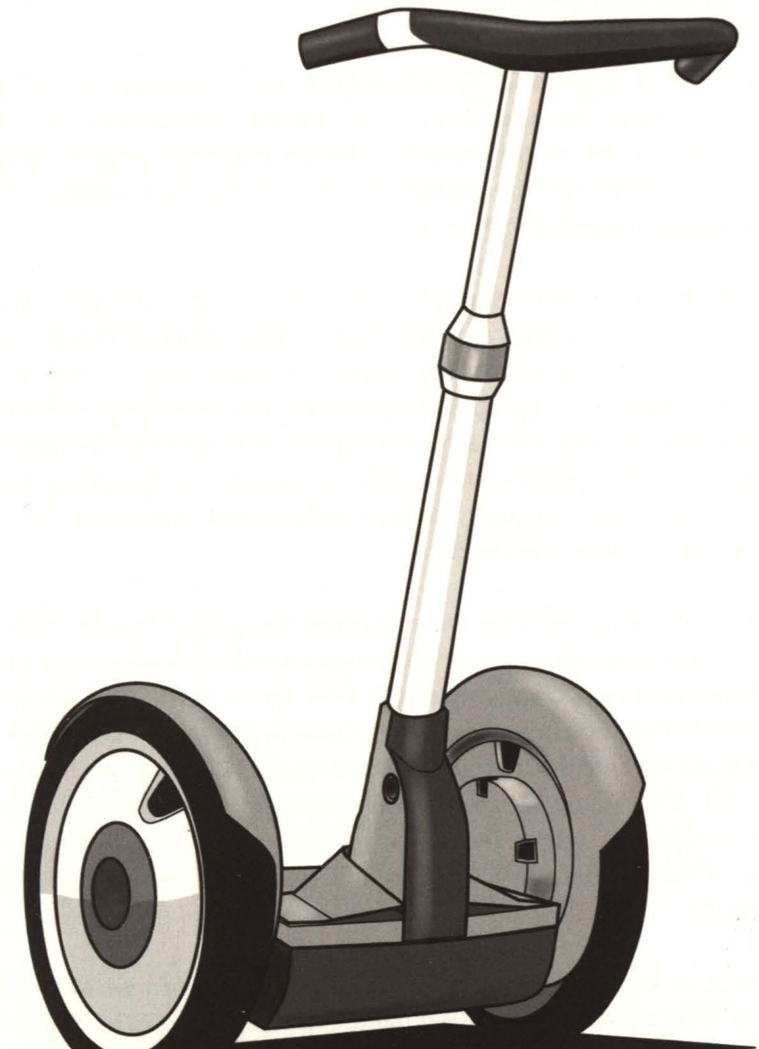


Figure 7.29 Segway HT
Source: Author.

braking energy back to the batteries. The company, Segway, was also heavily involved in developing lithium ion batteries for transport use.

Like the Sinclair C5 the Segway HT/PT was made to be as small as possible but where the C5 took the long and low approach, the Segway went tall and thin. The PT occupies a footprint not much bigger than two people standing side by side so it is capable of going almost anywhere that a walking human can.

However, the Segway PT has fallen foul of an anomaly in UK motoring laws (bbc.co.uk/news). On 18 January 2008 an owner in Yorkshire was fined for riding his Segway PT on the pavement (when it is perfectly legal in many US states and a number of European countries) because it is classed as a motor vehicle. This is an interesting test case for UK users since they are effectively barred from using the machines on pavements but cannot drive them on roads either because they do not pass all the requirements of a motor vehicle. This would appear to restrict use to private land and in response Segway is now actively working to improve UK regulatory acceptance of the HT/PT in line with other countries.

Segway does not rely on a single product and has diversified into other areas which make use of its dynamic stabilization system. These include rugged-terrain versions of the Segway HT and dedicated 'Patrol' versions for use by security services in large pedestrianized areas such as airports. Segway has also developed a Robotic Mobility Platform (RMP) which Segway's website (www.segway.com) describes as 'an extremely reliable and customizable transportation platform that is suitable for moving heavy payloads in tight spaces over a variety of terrain'.

SEGWAY PROJECT P.U.M.A. (PERSONAL URBAN MOBILITY AND ACCESSIBILITY) (USA)

In April 2009 Segway revealed a new prototype called Project P.U.M.A. (Personal Urban Mobility and Accessibility) co-developed with General Motors (Figure 7.30). Its purpose is to explore the possibility of a self-balancing two-wheeled vehicle powered by a lithium battery capable of reaching speeds of 35 mph for 35 miles (the Segway PT has a maximum speed of 12.5 mph). A significant innovation is the use of telematics systems to allow each machine to communicate with vehicles around it, reducing the risk of accidents and regulating the flow of traffic. The prototype P.U.M.A. was an open test-bed with a tubular structure but development has continued apace and SAIC has since become a collaborator alongside GM and Segway. In March 2010 at the Expo 2010, Shanghai, China three new concepts were exhibited called EN-V, short for Electric Networked-Vehicle (Figure 7.31) which were evolved from Project P.U.M.A. These were

Figure 7.30 Segway Project P.U.M.A.
Source: Courtesy of Segway (Press Release Photo).

fully functional two-person vehicles with advanced dynamics, connectivity, and sensory capabilities. They also had enclosed bodywork with styling by different studios within GM.

Since the EN-V (and its predecessor P.U.M.A.) are closer in concept to a small car with seated passengers, the rider's body mass cannot be used to direct the vehicle as on the upright Segway PT. Instead the battery pack is used as a counterbalance mounted on a track system. This moves fore and aft to adjust the centre of balance in place of the rider's body weight. Steering is by differential wheel rotation and braking is regenerative. The most significant feature of the EN-V is its use of telematics to communicate with vehicles around it in real time which can be used in active collision avoidance but also to make more efficient use of road space. Three different versions were displayed.

The Segway/GM/SAIC collaboration promises to be an interesting one because it represents one possible future for the motor industry and a focal point for most of the current design and technology drivers. This could be a portent of the real future of the urban microcar.

Figure 7.31 **Segway/GM/SAIC 'EN-V' (Electric Networked-Vehicle) Concepts**
Source: Courtesy of Segway (Press Release Photo).

Conclusions

In over a century of development an enormous amount of resources and investment have gone into the evolution of the conventional motor car. During most of the twentieth century it was the favoured mode of transport for individual journeys, and the IC engine became the dominant technology. The possession of motor cars became the badge of a developed Westernized economy.

Notwithstanding this fairly full list of examples, by comparison the resources and commitment which have gone into the design and development of microcars are much smaller in quantity. For the most part attempting to create designs for such vehicles, which could be put into production, has depended on the initiatives of individuals either within companies, or more often through independent small scale operations. Usually such individuals were responding to a perception of social and consumer needs, leading to creative dissatisfaction, and desire to design a way out the problem. The results can be seen in the list of attempts to devise microcars.

The difference in the early decades of the twenty-first century is that we are in the middle of a paradigm shift in transport. For a combination of reasons to do with energy security, and the environmental imperative to reduce our carbon footprint, there is need to both move away from the IC engine, and to develop lighter and more energy efficient vehicles. The time is ripe for the creation and development of microcars, and the evidence is of a wealth of ideas for how such vehicles might be designed.

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